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TECHNICAL REPORT 4964

EFFECT OF LONG TERM LOW-LEVEL GAMMA RADIATION ON THERMAL SENSITIVITY OF RDX/HMX MIXTURES

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NOVEMBER 1976

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report 4964

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE *(and Subtitle)*: Effect of Long Term Low-Level Gamma Radiation on Thermal Sensitivity of RDX/HMX Mixtures

5. TYPE OF REPORT & PERIOD COVERED: Final Report

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s):

Louis Avrami
Henry J. Jackson

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:

Picatinny Arsenal
Feltman Research Laboratory
Explosives Division
Dover, NJ 07801

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
1T161102AH5301
AMCMS Code 61102.11.H5301
Energetic Materials Research

11. CONTROLLING OFFICE NAME AND AODRESS:

12. REPORT DATE: November 1976

13. NUMBER OF PAGES: 22

14. MONITORING AGENCY NAME & AOORESS *(if different from Controlling Office)*:

15. SECURITY CLASS. *(of this report)*: Unclassified

15e. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. OISTRIBUTION STATEMENT *(of thie Report)*

Approved for public release; distribution unlimited.

17. OISTRIBUTION STATEMENT *(of the ebetract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if neceeeary and identify by block number)*

Gamma radiation	Weight loss
HMX	Impact sensitivity test
RDX	Vacuum stability test
DTA	Infrared spectrometry
TGA	Explosion temperature test

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Co^{60} HMX, RDX, HMX/RDX mixtures and Comp B were subjected to low level long-term gamma radiation (225 R/hr for 90, 120, and 150 days). Differential thermal analysis, thermogravimetric analysis, weight loss determination, and vacuum stability, infrared spectrometry, impact sensitivity and explosion temperature tests were used. It was found that the thermal stability and sensitivity of these explosives were not adversely affected by the exposures.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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INTRODUCTION

Nuclear density gauges using gamma rays are utilized in the RDX and HMX production lines at the Holston Army Ammunition Plant (HAAP), Kingsport, Tennessee. The gamma flux in these gauges is in the order of 225 Roentgen/hour (R/hr). During normal shutdowns of 90 to 120 days without decontamination of the operational equipment, explosive residues are subjected to long term low-level gamma irradiation, and HAAP became concerned over the possible effects of gamma rays on these explosives. This concern was based on information published by Mackenzie (Ref 1) who quotes Urizar et al. (Ref 2) in saying that the thermal stability of RDX, as determined by differential thermal analyses (DTA), is affected by irradiation.

In order to assure the safety of the operations at HAAP, the U.S. Army Armament Command requested that Picatinny Arsenal determine whether or not RDX/HMX residues could be subjected to sufficient irradiation under these conditions to adversely affect their thermal stability and, thereby, endanger production operations.

METHODS OF APPROACH

Literature Survey

A detailed search of both classified and unclassified literature was conducted to determine what information was available on the gamma irradiation of RDX, HMX, and their mixtures. In the work by Urizar et al. (Ref 2), HMX and RDX were irradiated in a nuclear power reactor, subjected to the combined steady-state effects of neutron and gamma radiation. Samples of the explosives were exposed at two flux levels. The first exposure involved a total neutron dose of $7 \times 10^{14} n/cm^2$ with a total gamma radiation of $5 \times 10^6 R$. The dose rates were, respectively, $6 \times 10^{10} n/cm^2$-sec and $3.6 \times 10^6 R/hr$. The second exposure was at a higher level. The total neutron dose was $2.6 \times 10^{16} n/cm^2$ with the gamma radiation being $2.4 \times 10^8 R$. At the second level the neutron dose rate was $3 \times 10^{11} n/cm^2$-sec and the gamma $1 \times 10^7 R/hr$. A three-gram sample of each explosive was irradiated in an individual evacuated quartz ampoule, then subjected to a variety of physical and chemical tests. Only minor effects of the irradiation were noted at the lower exposure level, but extensive deterioration occurred at the 10^{16} dose level. The Differential Thermal Analysis (DTA) results are discussed below.

The literature search revealed that one of the first investigations on the effects of gamma rays on explosives was conducted by the Los Alamos Scientific Laboratory and the Oak Ridge National Laboratory in 1948 (Ref 3). RDX, tetryl, TNT and Comp B were placed in activated uranium slugs for 10 days for a total gamma dose of $8.6 \times 10^6 R$. With a gamma dose rate of $3.6 \times 10^4 R/hr$, the low intensity of irradiation produced no visible changes in the explosives, the gas evolution was

slight, and the changes in the melting points were negligible.

In 1955 Warren et al. (Ref 4) irradiated a group of explosives, including RDX, with 0.41 Mev $_{79}Au^{198}$ gamma rays at three different temperatures (70°C, ambient, and -40°C) in order to determine the effect of radiation on the thermal stability of the explosives. In this experiment, the gamma dose rate averaged 10^5R/hr with total doses ranging from 1.2 to 4.8 x 10^7R. The vacuum stability test was used to determine the amount of gas evolved during and after irradiation. The gas evolved from the RDX sample during irradiation was 1.49 ml/gm in 44 days. After irradiation the evolution was 2.5 ml/gm in 40 days. Based on these results, Kaufman (Ref 5) stated that the lower limit of gamma-radiation dose at which decomposition could be detected was 10^6R.

Piantanida and Piazzia (Ref 6) performed a series of experiments on five explosives, including RDX, using Co^{60} gamma rays. The first utilized relatively brief exposures to high intensities; the second, long exposures to low intensities, and the third, very brief exposures to extremely small intensities followed by long aging. The second and third series of experiments were relevant to the situation at HAAP. The explosive samples in the second experiment were exposed to gamma rays of 10R/min for 70 days. Only a slight variation, which was barely noticeable, was found in the stability of RDX after irradiation. In the third series of tests the explosives were exposed to total doses of 10^4R for 20 minutes, 10^3R for 3.5 minutes, 10^2R for 3 minutes, and 10R for 0.3 minutes. After 180 days of aging at room temperature the samples were checked by the Taliani test[1] and no changes were found.

Berberet (Ref 7) exposed pellets of RDX and HMX to $_8Co^{60}$ gamma rays. The total doses ranged from 4.6 x 10^7R to 7 x 10^8R and the lowest dose rate was 2.3 x 10^6R/hr. At the lowest dose, a 1.2% weight loss was recorded. Both explosive specimens crumbled at the highest total dose.

Avrami, Jackson and Kirshenbaum (Ref 8) also conducted a study on HMX and RDX in powder and pellet form. These materials were irradiated with total Co^{60} gamma dose of 10^7, 10^8 and 10^9R at a dose rate of 6 x 10^5 R/hr. The effects were determined by the vacuum stability test, weight loss, thermogravimetric analysis, differential thermal analysis, melting point determinations of the five-second explosion temperature test, and a detonation velocity test. They found that HMX can withstand gamma radiation to a level of total dose of 1.0 x 10^8R, while RDX can withstand a level of 1.0 x 10^7R. In each case, properties of the explosive were gradually affected as a function of total dose

1. The Taliani test is conducted in a 120°C vacuum oven and the time taken to attain 300 mm of pressure is a measure of stability.

until complete deterioration occurred above the levels indicated.

In no instance did the survey reveal any data that indicated dose-rate dependency. Extrapolating total doses to exposures less than 10^6 - 10^7 R did not produce any meaningful data. The lack of low level long-term irradiation data did not permit comparison with equivalent total doses obtained with much higher dose rates (10^4 times greater) to determine whether or not a dose-rate dependency does exist.

Experimental Procedures

The experimental program was selected to duplicate the conditions at HAAP. The sample explosives were:

RDX
HMX
90/10 HMX/RDX
50/50 HMX/RDX
10/90 HMX/RDX
Comp B

The mixture selections were made to determine whether composition had an effect. The materials used were: RDX, Type B, Class A, Hol. Lot 21-18; HMX, Grade II, Class A, Hol. Lot SR 43-63; Comp B, Hol. Lot 050-5688.

The Co^{60} source at Picatinny Arsenal was used, and the explosive samples were exposed to an average dose rate of 225 R/hr for 90, 120 and 150 days (Table 1) in explosion-proof irradiation capsules developed at Picatinny Arsenal (Ref 8).

Table 1 - Co^{60} gamma irradiation data

Length of irradiation Days(hours)	Gamma dose rate R/hr	Total gamma dose R
90 (2160)	226.2	4.89×10^5
120 (2880)	225	6.48×10^5
150 (3600)	223.8	8.06×10^5

The powdered samples were irradiated at ambient conditions with hand-tightened caps on the irradiation capsules to simulate actual conditions. After each exposure, the explosive samples were tested to determine if any changes had occurred in any of the materials as compared to the results of the same tests with unirradiated materials. The test sequence was:

1. Differential Thermal Analysis (DTA)

The DTA studies on the explosive samples were performed with

a duPont 900 Differential Thermal Analyzer at a heating rate of 20°C/minute in a helium atmosphere. The technique is described elsewhere (Ref 1).

2. Thermogravimetric Analysis (TGA)

The TGA studies were conducted with the duPont 950 Thermal Gravimetric Analyzer which is an attachment to the duPont 900 DTA. A 20°C/minute heating rate (as in the DTA studies) was used, and the temperature at which a 10% weight loss occurred was recorded.

3. Weight Loss Determination

A direct measurement of weight loss was made for each explosive sample. The sample was weighed before and after irradiation.

4. Vacuum Stability Test

The vacuum stability test (VST) was conducted at 100°C for 40 hours with one gram samples of explosive.

5. Infrared Spectrometry

The infrared spectra for the explosives were obtained by using the KBr (potassium bromide) pellet technique.

6. Impact Sensitivity Test

The Picatinny Arsenal impact machine was used with a 2-kg dropweight to determine the effect of gamma radiation on the sensitivity of each explosive to mechanical impact. The 50% fire point was obtained by the Bruceton Up-Down Method while the Picatinny Arsenal Test Method was used for the 10% point.

7. Explosion Temperature Test

The confined, or closed, explosion temperature test of Henkin and McGill (Ref 9) with modifications (Refs 10 through 12) was used to determine the time to explosion at a given temperature.

RESULTS

From the DTA studies, the onset and peak temperatures for the endotherms and exotherms are listed in Table 2. Typical DTA thermograms of unirradiated and irradiated RDX and HMX are displayed in Figures 1 through 4.

The change in mass as a function of temperature was measured by the TGA method. The TGA thermograms are sufficiently reproducible to permit the determination of the temperature-stability ranges of the

explosive materials. The results for each of the explosive materials obtained as a function of total dose are listed in Table 3.

The weight of each explosive was recorded before and after irradiation while the explosive was in the quartz vial. These results are listed in Table 4.

For the 100°C vacuum stability test only the samples irradiated for 150 days were tested, and the results (listed in Table 4) are compared to literature data for the unirradiated materials. The IR spectra of all the irradiated explosives were identical to the control IR spectra. No color changes were induced in any of the explosives by the irradiation.

The impact sensitivity test results for the 10% and 50% points as function of total gamma dose are listed in Table 5.

The explosion temperature data were utilized in a computer program to determine the apparent activation energy and the explosion temperatures for 1 second, 5 seconds and 10 seconds. Only an apparent activation energy is determined since the explosive is not subjected simultaneously to isothermal heating. The 5-second explosion temperature is the value usually reported. The results are listed in Table 6.

DISCUSSION

The DTA thermograms of RDX (Figures 1 and 2) show minimal changes between the control sample and the sample irradiated for 150 days. From Table 2 it is evident that the 90- and 120-day gamma irradiation did not cause any significant changes. For each of the irradiated samples, no exothermic reaction occurred between 50°C and 150°C as reported by Urizar (Ref 2).

Figures 3 and 4 are the thermograms for the control HMX and the 150-day irradiated HMX, respectively. Although the curves are very similar, two slight differences are visible. The two endotherms in the control sample at 181°C and 262°C are shifted upwards as a result of the irradiation. The first endotherm is the crystal transformation occurring at 181°C when the monoclinic β-HMX changes to the δ-form (Ref 13). The other endotherm is the melting point which leads immediately into decomposition. Since no drastic downward shift occurred in the endotherms or exotherm, it can be concluded that the thermal stability of the HMX was not affected by the 150-day gamma irradiation. A closer look at Figure 4 does show very slight indications of an exothermic reaction just before each endotherm (an increase of $\Delta T \leq 0.2^{\circ}C$). Although the slight surge at the higher temperature ($\sim 275^{\circ}C$) is probably a part of the decomposition process, the cause of the initial rise ($\sim 183^{\circ}C$) could not be determined due to the very small exothermic change.

Urizar et al. (Ref 2) reported that the reactor-irradiated (neutrons and gammas combined) HMX and RDX produced a DTA curve which exhibited an exotherm beginning at 50°C to 75°C and peaking at 155°C to 160°C with a $\Delta T \sim 1\text{-}2^{\circ}C$. Longhran (Ref 14) indicated that a small exotherm occurs only with a gamma dose > 10^7 R. This also can be seen in the results for HMX reported by Avrami et al. (Ref 8) at doses of 1.1×10^8 R. It was concluded that the slight exothermic reaction before the $\beta \rightleftarrows \delta$ HMX polymorphic transition could be caused by a radiation-induced impurity or diffusion of occluded gases which would have no effect on its sensitivity or stability. In this study and in the work reported by Avrami et al. (Ref 8) no exotherms prior to melting point endotherm were produced in the DTA curves of gamma irradiated RDX.

A comparison of the DTA curves of RDX and HMX (Figures 1 through 4) with those in the literature (Refs 15 through 17) showed some differences. These are attributed to (1) the purity and particle size of the material, (2) the atmosphere (N_2, He or air) in which the sample was run, (3) the equipment used, and (4) the heating rates. The RDX/HMX and Comp B used in this experiment were military grade materials from the production line, whereas the materials normally described in the literature were of reagent quality.

The work of Castorina et al. (Ref 18) may give further insight to the formation of the slight exotherm preceding the melting point endotherm produced in HMX by gamma radiation. Those investigators studied the surface activity of gamma-HMX in vacuo and in H_2O, NO and NO_2 vapors as a function of Co^{60} gamma dose. They found that when gamma-HMX was irradiated in relatively low doses (ranging from about 1×10^6 to 7×10^7 R), adsorbed water molecules interacted with the substrate to form polar adducts. The dose had no appreciable effect on the bulk molecules except, perhaps, to produce excited states which eventually populated the surface. With higher doses the probability of an exothermic reaction occurring is more likely.

With the 50/50 HMX/RDX, 90/10 HMX/RDX, 10/90 HMX/RDX and Comp B samples, the DTA curves of the irradiated samples did not show any significant differences from the control samples. The TGA data of the control and irradiated samples shown in Table 3 reveal that in none of the HMX/RDX samples, control or irradiated, did the onset of decomposition occur below 180°C, while in the Comp B samples decomposition onset occurred near 130°C. This also indicates that the thermal stability of these materials was not adversely affected by the gamma radiation.

The results in Table 4 for weight loss measurements, vacuum stability tests, and infrared spectra did not reveal any significant differences between the control and irradiated samples. The weight losses were small and the slight increases are attributed to the high humidity prevalent during the irradiations at ambient conditions.

The changes were sufficiently small to be considered within experimental error.

The impact test results listed in Table 5 did show some changes in that some of the samples showed an increase in the height of the 50% point, while others showed a decrease. However, more importantly, from a safety point of view, the gamma irradiations for practically all of the explosives did not cause any increase in the 10% point sensitivity, i.e., there was no decrease in the height of drop for the 10% point. In the case of HMX and RDX, the height of the 10% point was greater with the irradiated sample than with the control, whereas, Comp B did not show any significant change. Since the 10% point in the Picatinny Arsenal Test is usually one fire in ten trials, the statistics cannot match those obtained with the Bruceton test for the 50% point. In order to determine whether any significant differences did occur at the 10% point, an analytical sensitivity test procedure designed by Einbinder (Ref 19) was applied to one irradiated and one control sample of RDX. The sequential test procedure was implemented at the 10% level for both RDX irradiated for 150 days and for the control sample. Although the irradiated sample had a 10% fire level of 23.5 cm (9.25 inches) compared to 19.69 cm (7.75 inches) for the control, the 95% confidence levels for both samples overlapped, indicating that there was no statistically significant difference in impact sensitivity.

From the explosion temperature results in Table 6, it is evident that the low level long-term gamma irradiation did not have a significant effect on the thermal sensitivity of the explosives. The results are consistent within themselves, that is, the apparent activation energy is higher for HMX than RDX and the values for the HMX/RDX control and irradiated mixtures fall between those for RDX and HMX.

CONCLUSIONS

Long term low-level gamma irradiation (225R/hr for 90, 120, or 150 days) had no significant effect on the thermal stability or thermal and impact sensitivities of RDX, HMX, selected HMX/RDX mixtures, and Comp B. Exposure of RDX, HMX, and Comp B to gamma radiation from in-line density gauges at HAAP during shutdown periods should not have an adverse effect on the sensitivity or stability of these explosives.

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TABLE 2

Differential thermal analysis of gamma-irradiated explosives

Heating rate - 20°C/min in helium

Gamma exposure rate - 225 R/hr

Explosive	Total dose(R)	Endotherm Onset (°C)	Endotherm Peak (°C)*	Exotherm Onset (°C)	Exotherm Peak (°C)
RDX	0	180	192,196	203	247
	4.9×10^5	175	191,200	206	257
	6.5×10^5	175	201	207	255
	8.1×10^5	160	198	205	245
HMX	0	175,260	181,262	265	273
	4.9×10^5	177,263	180,265	267	274
	6.5×10^5	184,275	186,277	278	287
	8.1×10^5	183,275	187,277	279	287
50/50 HMX/RDX	0	160	192,193	218	250
	4.9×10^5	155	190,193	206	265
	6.5×10^5	160	190,193	204	268
	8.1×10^5	184	192,196	210	280
90/10 HMX/RDX	0	182	190,197	230	282
	4.9×10^5	155	190,192,195,197	220	280
	6.5×10^5	170	189,193,199,201	230	282
	8.1×10^5	165	190,195,198	210	277
10/90 HMX/RDX	0	160	191,195	205	248
	4.9×10^5	187	194,200	207	270
	6.5×10^5	170	193,198	209	250
	8.1×10^5	160	195,197	205	250
Comp B	0	70	78	195	238
	4.9×10^5	70	77	187	240
	6.5×10^5	70	77	183	233

*Underlined temperatures denote maximum peaks.

TABLE 3

Thermogravimetric analysis of gamma-irradiated explosives

Heating rate - 20°C/min in helium
Gamma exposure rate - 225 R/hr

Explosive	Total dose (R)	Weight (mg)	Onset of decomposition (°C)	10% Weight loss temp (°C)	Total weight loss (%)	Remarks
RDX	0	5.3	205	233	94.3% @ 290°C	
	4.9×10^5	3.17	195	228	96.8% @ 275°C	
	6.5×10^5	3.5	190	223	100% @ 268°C	
	8.1×10^5	4.15	190	223	95.2% @ 260°C	
HMX	0	3.45	255	-	7.2% @ 291°C	Det. @ 291°C
	4.9×10^5	3.6	260	-	8.3% @ 293°C	Det. @ 293°C
	6.5×10^5	3.25	250	-	6.1% @ 287°C	Det. @ 287°C
	8.1×10^5	4.50	250	-	6.7% @ 290°C	Det. @ 290°C
	8.1×10^5	3.03	245	-	9.2% @ 287°C	Det. @ 287°C
50/50 HMX/RDX	0	3.05	185	232	93.4% @ 305°C	
	4.9×10^5	2.93	185	232	93.2% @ 305°C	
	6.5×10^5	4.26	185	233	97.7% @ 305°C	
	8.1×10^5	5.70	180	218	100% @ 300°C	
	8.1×10^5	4.00	190	222	95% @ 305°C	
90/10 HMX/RDX	0	3.5	185	243	24.3% @ 291°C	Det. @ 291°C
	4.9×10^5	3.45	185	265	19.4% @ 289°C	Det. @ 289°C
	6.5×10^5	3.5	190	283	17% @ 292°C	Det. @ 292°C
	8.1×10^5	3.94	185	260	18.3% @ 286°C	Det. @ 286°C
	8.1×10^5	3.8	185	240	26.3% @ 297°C	Det. @ 297°C
10/90 HMX/RDX	0	3.4	185	233	100% @ 305°C	
	4.9×10^5	3.7	185	225	84% @ 295°C	
	6.5×10^5	3.85	180	225	94.8% @ 295°C	
	8.1×10^5	3.2	180	220	95.6% @ 300°C	
Comp B	0	2.4	130	188	87.5% @ 275°C	
	4.9×10^5	4.75	135	207	91.6% @ 295°C	
	6.5×10^5	3.05	135	205	90.2% @ 300°C	
	8.1×10^5	4.83	135	185	92.7% @ 300°C	

TABLE 4

Effect of low level long-term gamma radiation on weight loss, vacuum stability and infrared spectrum

Gamma dose rate - 225 R/hr

Explosive	Total dose (R)	Weight loss (gm)	Weight loss %	100°C VST 40 hr (ml/gm)	I R spectrum
RDX	0	0		0.09 (8)	
	4.9×10^5	+0.0020	+0.07%		No change
	6.5×10^5	-0.0012	-0.03%		No change
	8.1×10^5	-0.0013	-0.04%	0.27	No change
HMX	0	0		0.37	
	4.9×10^5	+0.0015	+0.04%		No change
	6.5×10^5	-0.0014	-0.04%		No change
	8.1×10^5	+0.0005	+0.01%	0.15	No change
50/50 HMX/RDX	0	0			
	4.9×10^5	+0.0010	+0.03%		No change
	6.5×10^5	-0.0003	-0.01%		No change
	8.1×10^5	0.0000	0%	0.23	No change
90/10 HMX/RDX	0	0			
	4.9×10^5	+0.0015	+0.04%		No change
	6.5×10^5	-0.0035	-0.10%		No change
	8.1×10^5	-0.0010	-0.02%	0.21	No change
10/90 HMX/RDX	0	0			
	4.9×10^5	+0.0016	+0.04%		No change
	6.5×10^5	-0.0011	-0.03%		No change
	8.1×10^5	-0.0004	-0.01%	0.27	No change
Comp B	0	0		0.70	
	4.9×10^5	+0.0006	+0.02%		No change
	6.5×10^5	-0.0015	-0.04%		No change
	8.1×10^5	-0.0030	-0.10%	0.40	No change

TABLE 5

Effect of low level long-term gamma radiation on impact sensitivity

Gamma dose rate - 225 R/hr

Explosive	Total dose (R)	P.A. Method* 10% point (cm)	P.A. Method* 10% point (in.)	Bruceton Method 50% pt. (cm)	Bruceton Method 50% pt. (in.)
RDX	0	15.2	6	43.87 ± 3.58	17.27 ± 1.41
	4.9×10^5	22.9	9	44.22 ± 5.23	17.41 ± 2.06
	6.5×10^5	17.8	7	34.67 ± 9.96	13.61 ± 3.92
	8.1×10^5	38.1	15	46.56 ± 6.17	18.33 ± 2.43
HMX	0	22.9	9	34.98 ± 2.44	13.77 ± 0.96
	4.9×10^5	20.3	8	36.20 ± 6.02	14.25 ± 2.37
	6.5×10^5	25.4	10	37.80 ± 2.36	14.88 ± 0.93
	8.1×10^5	30.5	12	41.90 ± 4.55	16.50 ± 1.79
50/50 HMX/RDX	0	15.2	6	50.22 ± 6.17	19.77 ± 2.43
	4.9×10^5	22.9	9	43.84 ± 11.61	17.26 ± 4.57
	6.5×10^5	22.9	9	39.17 ± 4.22	15.42 ± 1.66
	8.1×10^5	35.6	14	38.94 ± 8.92	15.33 ± 3.51
90/10 HMX/RDX	0	17.8	7	45.92 ± 3.86	18.08 ± 1.52
	4.9×10^5	27.9	11	41.28 ± 7.06	16.25 ± 2.78
	6.5×10^5	25.4	10	36.40 ± 4.80	14.33 ± 1.89
	8.1×10^5	25.4	10	36.27 ± 5.00	14.28 ± 1.97
10/90 HMX/RDX	0	17.8	7	54.41 ± 3.86	21.42 ± 1.52
	4.9×10^5	12.7	5	49.81 ± 3.25	19.61 ± 1.28
	6.5×10^5	20.3	8	44.48 ± 14.38	17.51 ± 5.66
	8.1×10^5	33.0	13	51.44 ± 4.32	20.25 ± 1.70
Comp B	0	43.2	17	56.92 ± 6.17	22.41 ± 2.43
	4.9×10^5	40.6	16	55.75 ± 1.88	21.95 ± 0.74
	6.5×10^5	40.6	16	54.25 ± 7.09	21.36 ± 2.79
	8.1×10^5	40.6	16	49.34 ± 3.18	19.42 ± 1.25

*Picatinny Arsenal Impact Test: 2 kg weight; room temperature about 72°F and 55% to 60% relative humidity.

TABLE 6

Effect of low level long-term gamma radiation on explosion temperature

Explosive	Total dose (R)	E_a - apparent activation energy (Kcal/mole)	Explosion temperature (°C) (1 sec)	(5 sec)	(10 sec)
RDX	0	13.69	322.9°C	250.1	223.9
	4.9×10^5	15.67	317.0	253.6	230.3
	6.5×10^5	14.34	336.2	263.3	237.0
	8.1×10^5	16.78	320.7	260.4	238.0
HMX	0	30.78	327.2	292.0	278.0
	4.9×10^5	29.17	338.3	300.0	284.8
	6.5×10^5	27.50	332.2	292.4	276.8
	8.1×10^5	38.27	321.5	293.4	282.0
50/50 HMX/RDX	0	16.43	327.4	264.6	241.4
	4.9×10^5	16.19	339.5	273.4	249.1
	6.5×10^5	18.57	331.3	274.4	253.0
	8.1×10^5	15.46	339.0	270.2	245.1
90/10 HMX/RDX	0	15.91	362.7	290.7	264.4
	4.9×10^5	18.05	350.5	288.4	265.3
	6.5×10^5	22.05	343.4	292.8	273.5
	8.1×10^5	14.20	384.8	299.9	269.7
10/90 HMX/RDX	0	13.26	328.8	252.5	225.3
	4.9×10^5	18.91	316.0	262.6	242.5
	6.5×10^5	14.71	332.0	261.6	236.1
	8.1×10^5	17.17	325.9	265.8	243.5
Comp B	0	18.88	307.8	255.8	236.1
	4.9×10^5	12.21	337.4	253.2	223.7
	6.5×10^5	17.69	312.9	256.7	235.8
	8.1×10^5	19.22	306.0	255.1	235.9

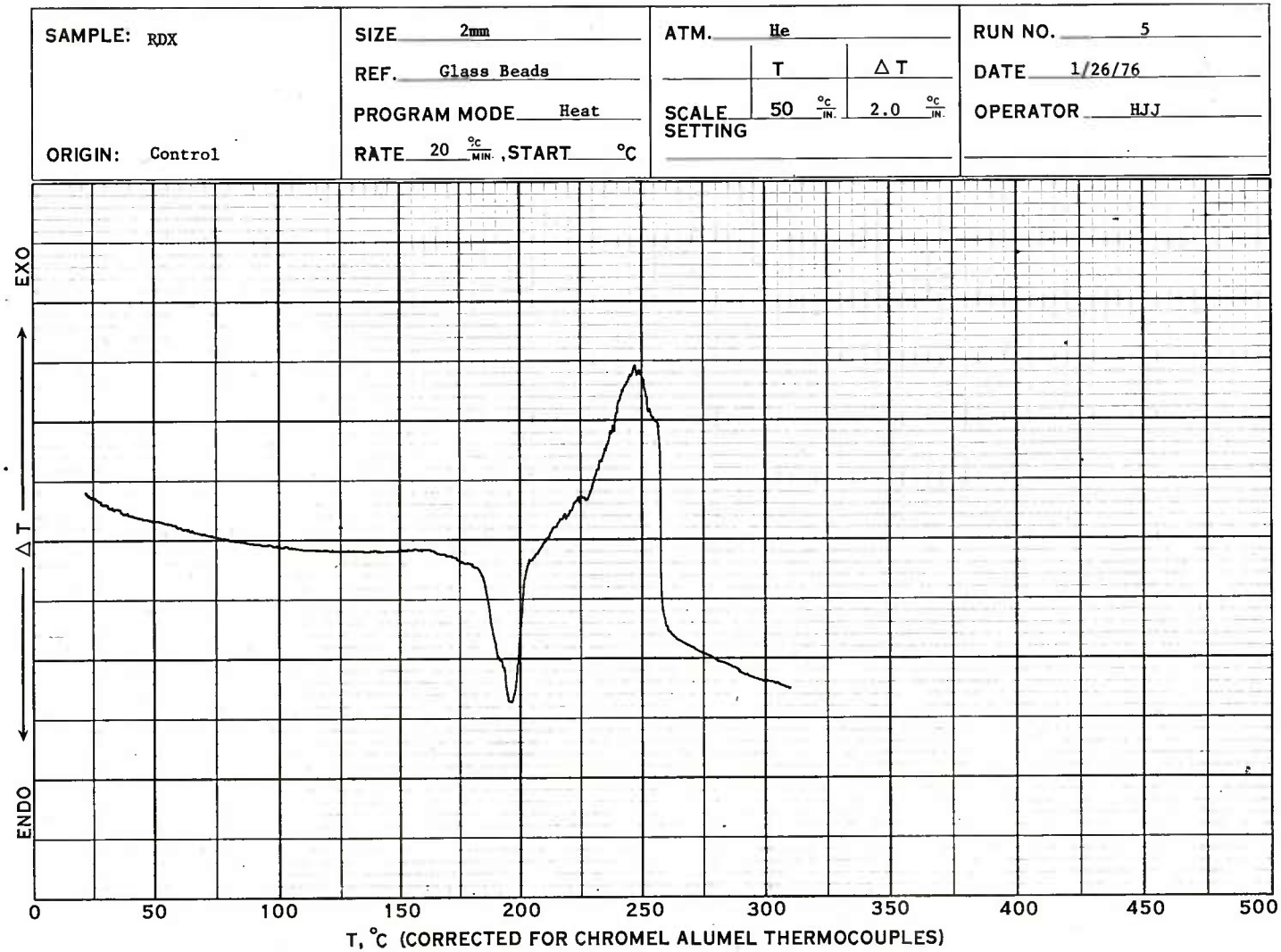

Figure 1. DTA thermogram for unirradiated RDX

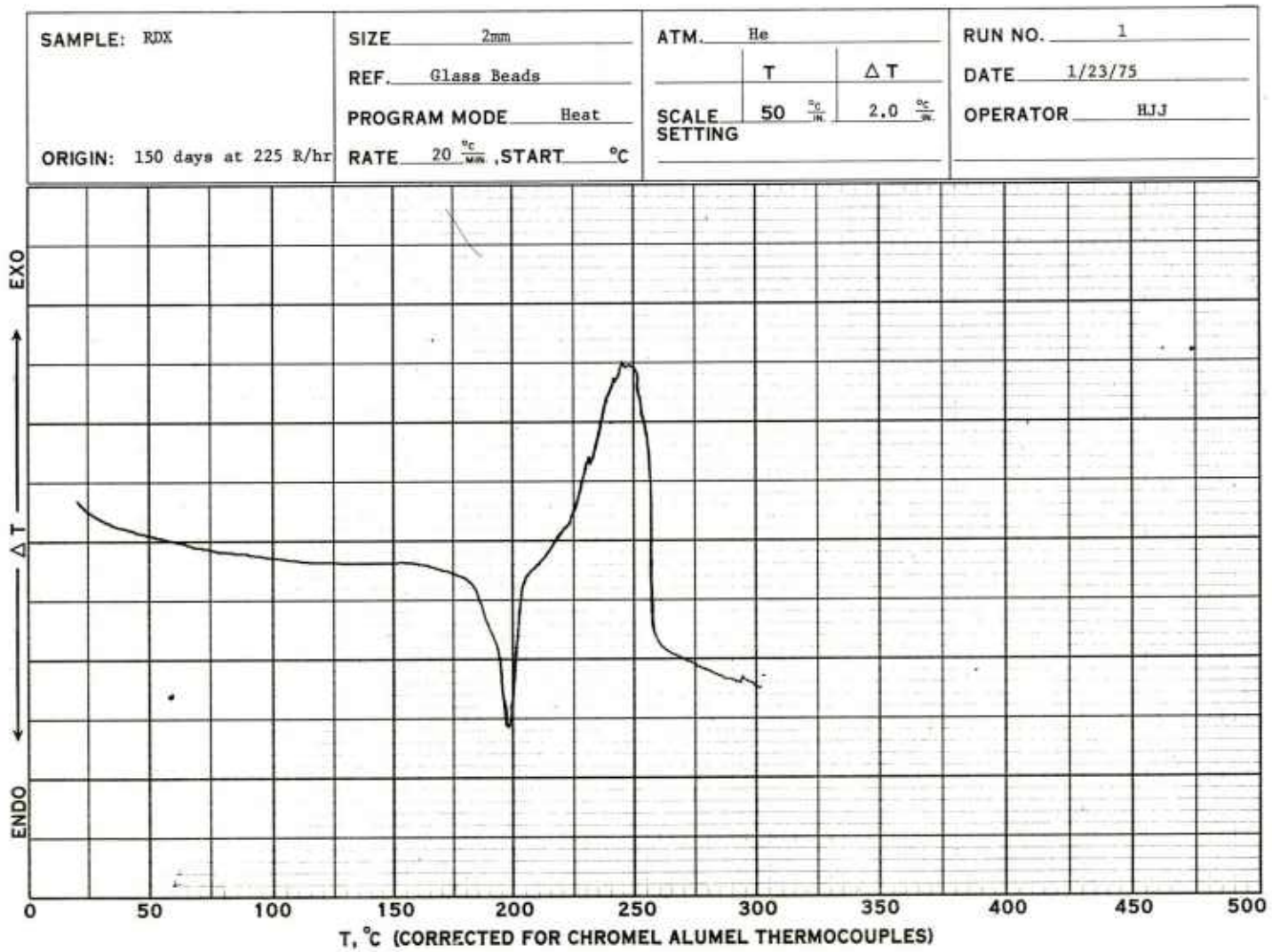

Figure 2. DTA thermogram for RDX gamma irradiated for 150 days at 225R/hr

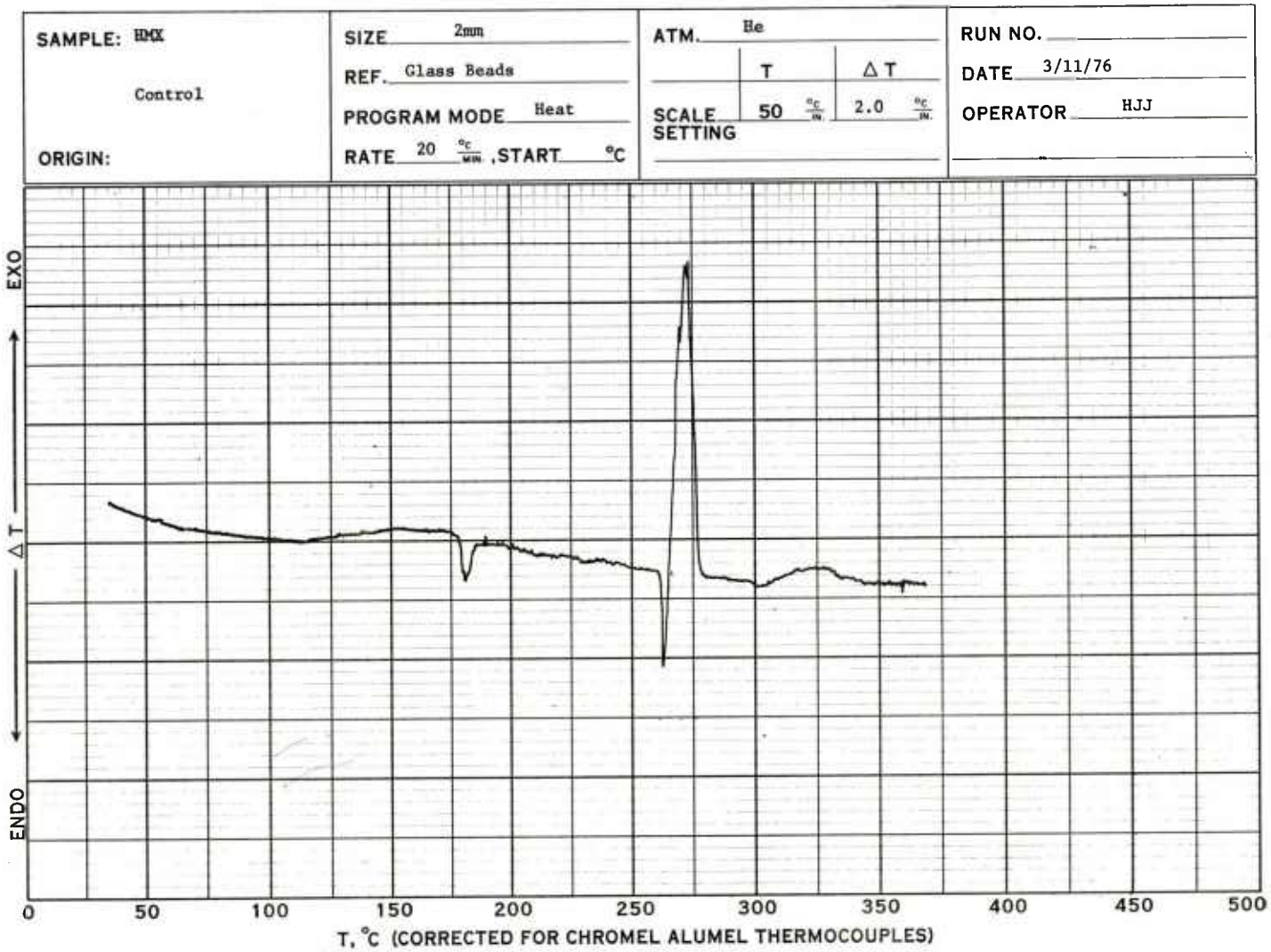

Figure 3. DTA thermogram for unirradiated HMX

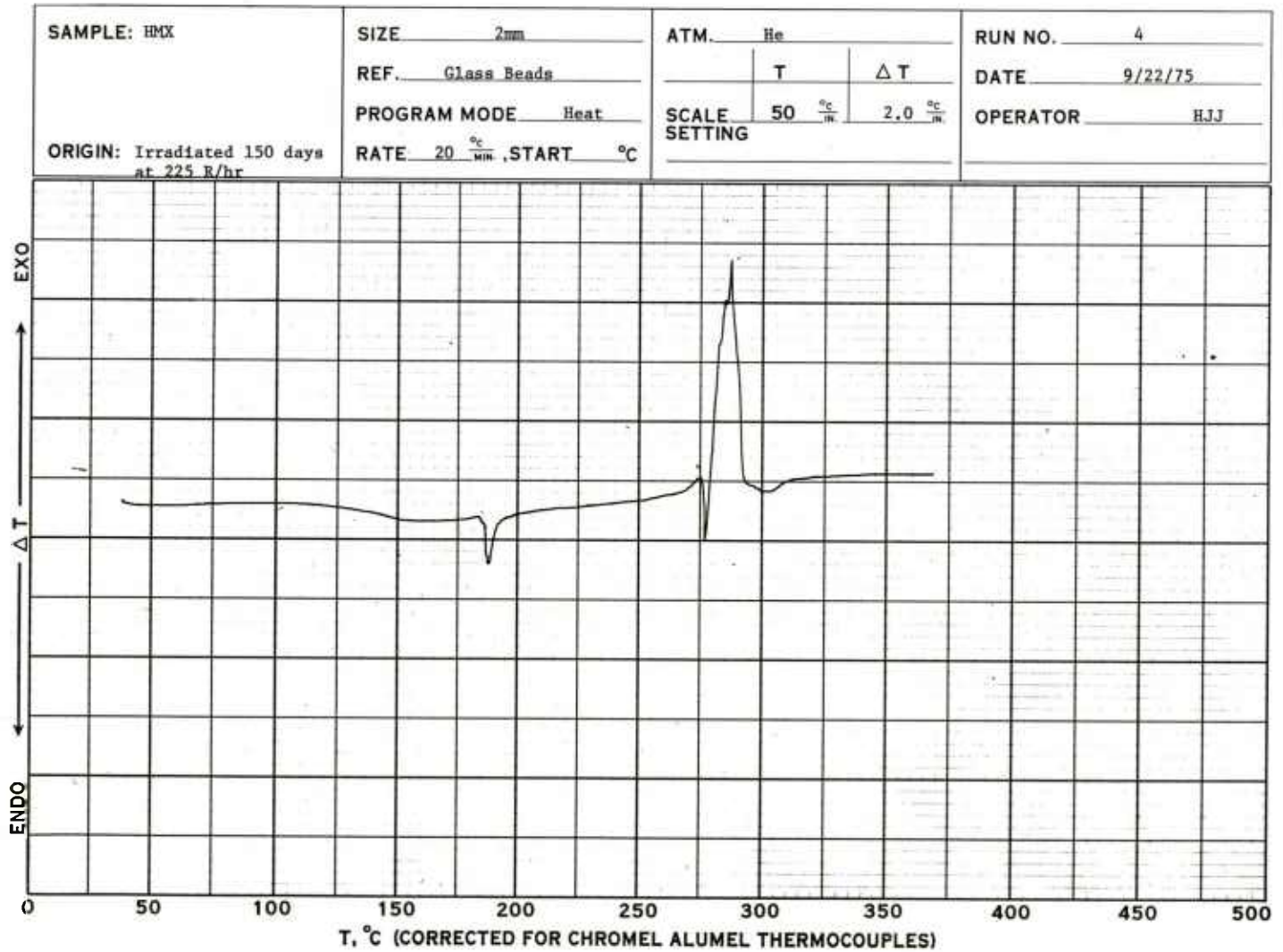

Figure 4. DTA thermogram for HMX gamma irradiated for 150 days at 225R/hr

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